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The Determinants of Remanufacturing Practices in Developing Countries: Evidence from Thai Industries

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Abstract

Remanufacturing represents a significant End-of-Life (EoL) process for gaining environmental and economic advantages by extending product longevity, whilst reducing raw material consumption. Due to paucity of relevant empirical studies, this study aims to bridge the gap in remanufacturing knowledge by investigating the significant factors influencing firms' decisions to conduct remanufacturing in three Thai industries, namely automotive parts, photocopiers and agricultural machinery. This research combined qualitative and quantitative approaches involving the use of semi-structured interviews and questionnaires. Our results show that across all three industries, the most powerful determinant driving the decision making of firms constitute factors within the area of business feasibility, followed by elements in a firm's strategic factors and policy factors. Environmental regulations comprise the least important variable. Among the subordinate factors, financial aspects are ranked as the most crucial factor for conducting remanufacturing and acquiring cores matters for remanufacturing firms to increase their profit margins. All industries perceive product maturity, especially in terms of product lifespan, technological change and complexity, as the second most crucial factor in remanufacturing. As the industries under consideration are labor-intensive, skilled workers are needed and this is ranked as the third most influential factor to expedite remanufacturing. The firm's characteristics and the structure of particular industries are important in identifying the impact of influencing factors. A comprehensive development of policies and strategies and robust governmental support are needed to develop remanufacturing in Thailand.

Keywords Remanufacturing; Thailand; Automotive parts; Photocopiers; Agricultural Machinery; Factors influencing decision-making

1. Introduction

With growing concerns regarding environmental protection, many businesses have been encouraged to address environmental issues and face many challenges in doing this (Jiang et al., 2011). Remanufacturing represents a significant End-of-Life (EoL) process, which could potentially generate both environmental and business benefits. It extends product longevity while reducing raw material consumption, energy usage and environmental impact (Subramoniam et al., 2013). Hence, remanufacturing is considered a key strategy for promoting sustainable development (Matsumoto and Ijomah, 2013).

By definition remanufacturing is "the process of returning a used product to at least OEM (Original Equipment Manufacturer) original performance specification from the customers' perspective and giving the resultant product a warranty that is at least equal to that of a newly manufactured equivalent" (Ijomah, 2002). In reducing the utilization of raw materials, remanufacturing represents a great opportunity to construct a win-win situation for all relevant players, i.e. customers, businesses, the environment and society at large (Sharma et al., 2014). Remanufacturing also offers producers a method for avoiding waste limitation penalties by reintroducing waste matter into the manufacturing cycle (Ijomah et al., 2004).

In recent times remanufacturing has been concentrated in developed countries. In the U.S. a contemporary survey found over 6,000 firms engaged in remanufacturing, involving approximately 113 remanufactured goods (Lund and Hauser, 2010). Surveys of the U.S. and European manufacturing sector have indicated that remanufacturing contributes both high economic value and additional advantages to the economies involved (Subramoniam et al., 2010) and, therefore, deserves considerable attention from researchers (Kerr and Ryan, 2001).

Within developing countries remanufacturing practices have also recently become more important. Increased involvement with multinational enterprises, liberalization in investment and trade policies, as well as overconsumption of natural resources have all helped to encourage remanufacturing in these countries. China has pointed to remanufacturing as representing a key future manufacturing initiative within their National Long and Medium Term Program of Science and Technology Development Planning (Xiang and Ming, 2011); while in India GE Healthcare and Caterpillar have both realized remanufacturing advantages through either expanding their related activities or having plans to do so in the future (Rathore et al., 2011).

Although the remanufacturing approach is gaining popularity in developing countries, remanufacturing research remains in its infancy; with most research projects being conducted in China, India or Brazil. Yet it is important to understand the factors which have a bearing on the uptake of remanufacturing in developing countries because of the increasing industrialization of such countries and the threat of undesirable environmental repercussions if sustainable manufacturing approaches are not widely adopted in these nations. ~~Moreover,~~ Lund (1984) has highlighted the importance of remanufacturing to developing countries. In response to the sparse number of empirical studies conducted in a developing country context, our research objective is to investigate the significant factors influencing a firm's decisions to conduct remanufacturing focusing on three industries in Thailand, namely automotive parts, photocopiers and agricultural machinery, as case studies. These three types of product were chosen because they constitute the top three industries in Thailand which are suitable for remanufacturing (Kohpaiboon et al., 2011). The domestic markets for these products are

considerable[1] and different degrees of remanufacturing have occurred within the three industries over a long period of time.

~~In addition,~~ Thailand has the potential to become the remanufacturing hub of the Association of South East Asian Nations (ASEAN) countries because it has been thoroughly integrated into the global manufacturing network of leading multinational companies. Its workforce, therefore, has accumulated the manufacturing knowledge necessary for undertaking remanufacturing (Kohpaiboon et al., 2011). ~~Furthermore,~~ With the opening of Myanmar and the establishment of the ASEAN Economic Community (AEC), Thailand has the capacity to export remanufactured products to other ASEAN countries, especially CLMV, i.e. Cambodia, Laos, Myanmar and Vietnam (Kohpaiboon et al., 2012).

The rest of the paper is organized as follows. The second section presents a literature review with emphasis on the key factors influencing firms' decisions to conduct remanufacturing. The next outlines the methods and materials. The findings and a discussion make up section four, while the conclusions and contributions comprise the final section.

2. Literature Review

The factors affecting the decision of a firm to conduct remanufacturing can be grouped into three main areas, namely business feasibility, firm's strategic factors and policy factors. There are also thirteen subordinate factors based on the prior literature (Figure 1).

2.1 Business Feasibility

There are four strategic factors impacting on remanufacturing profitability. First, technical aspects comprise product design and the product's capacity to be disassembled and re-assembled. When making products more remanufacturing-friendly, product design must take into account remanufacturability (Subramoniam et al., 2010) and product life cycle costs (Ijomah, 2009). The basic design requirements for a product to be suitable for remanufacturing are that it may be easily disassembled, cleaned, replaced and re-assembled (Zhang et al., 2011).

The second aspect of product maturity is related to both the speed of technological change and physical lifespan of products (Matsumoto, 2010). If a new product is subject to rapid technological change, component replacement is recommended, rather than remanufacturing. Likewise, if the lifespan of a product is prohibitively short, it is unsuitable for remanufacturing.

Since remanufacturing is labor intensive, the third influencing factor concerns the availability of skilled workers. As argued by Lundmark et al. (2009), the remanufacturing process tends to be quite complex and must be handled by skilled workers. Workers should be fully cognizant of a product's specifications in order to be able to both disassemble it and identify any parts to be replaced in order to replicate its original performance. ~~However,~~ The

[1] Markets of automotive parts depend mainly on automotive industries. In 2013, Thailand was ranked as the 9th automobile producers in the world (OICA, 2014) and 1st largest in ASEAN and a major regional production base for automotive parts (TAI, 2012). Leading automobile multinational firms are located in Thailand, for example Toyota, Honda, Nissan, General Motors, and BMW. Domestic and export sales of automotive industry totally accounts for 10% of Thai gross domestic product (GDP). The market values estimate of used photocopier in Thailand was approximately US$ 60 million or account for 50% of new products. Importantly, leading multinational photocopier firm, Fuji-Xerox, has also established remanufacturing operation in Thailand. For agricultural machinery, its production values over US$ 300 million has increased over three times within over two decades (Kohpaiboon et al., 2011).

key importance of remanufacturing is that in comparison to conventional manufacturing, it requires proportionally much less skilled labor (Lund, 1984).

The final factor comprises the financial aspects that play a major role in conducting remanufacturing. Both the costs involved in establishing remanufacturing operations and the demand for remanufactured products represent two drivers impacting business profitability. The majority of costs incurred in remanufacturing arise from the additional resources required to return the product to its original performance capabilities. Such costs include expenses connected to direct production, quality assurance, and establishing the reverse logistics network necessary to acquire cores.[2] Many researchers emphasize the role of effective reverse logistic networks since they are considered the backbone of remanufacturing operations (Matsumoto, 2010). Sufficient demand for remanufactured goods is needed to sustain businesses. Seitz (2007) argued that the profitability of remanufacturing depends mainly on the customer demand for remanufactured goods. However, customers may have a negative perception of remanufactured products because they believe they may be of inferior quality compared to new goods (Abdulrahman et al., 2015).

2.2 Firm's Strategic Factors

Five firm-level strategic factors represent additional key variables determining the success of remanufacturing businesses. Undoubtedly, the global growth in environmental concerns and the importance of corporate social responsibility (CSR), have led many businesses to increasingly offer green products to their consumers (Subramoniam et al., 2010). Environmental and ethical concerns represent the important motives affecting decisions to undertake remanufacturing in China (Wei et al., 2015).

~~In addition,~~ Remanufacturing potentially offers business and marketing benefits through building new business strategies concerning product life cycles and creating new product sales through trading used products (Östlin, 2008). This allows firms to acquire feedback information regarding customer needs, market solutions and product design. Securing a supply of spare parts through remanufactured products represents another business benefit by reducing the dependency on suppliers after the termination of production lines (Östlin et al., 2008).

Brand Protection may be seen as a third factor when considering firm strategy. OEMs have full information concerning product design, specifications and materials sourcing. ~~Therefore,~~ They are able to either run remanufacturing operations in-house or outsource them. ~~However,~~ OEMs generally prefer to run in-house remanufacturing, instead of outsourcing, in order to protect their brand image and lower any risk of products that have gone through an inferior process of remanufacturing being categorized as "remanufactured" when the process has been expedited by Independent Remanufacturers (IRs) (Seitz, 2007). Brand protection, however, causes difficulties for IRs when attempting to operate as they lack cooperation from OEMs (Östlin, 2008).

A fourth factor that might affect firms choosing to remanufacture concerns about

[2] Core is a used product that is a main component of a particular remanufacturing process, for example a used automotive part or used photocopier.

cannibalization effects. Remanufacturing conducted by OEMs may have a negative impact on the manufacture of new products (Matsumoto, 2010). The belief that remanufacturing might kill the prospect of new products may lower any motivation to remanufacture (Saavedra et al., 2013). However, some remanufactured and new products target different market segments, diluting any cannibalization effects (Östlin et al., 2008).

As organizational aspects, building effective management within organizations promoting alignment, integration and communication among remanufacturing and other sections represents a critical factor influencing the success of an operation (Abdulrahman et al., 2015). Subramoniam et al. (2010) emphasized the importance of organizational aspects through integrating remanufacturing within original manufacturing operations.

2.3 Policy Factors

Four noteworthy aspects concerning policy factors also have considerable influence. The rules and regulations involved in setting up remanufacturing businesses vary from country to country. Mondal and Mukherjee (2006) confirmed that weak legislation prohibits remanufacturing acceptance in the Indian computer and electronics industry. Likewise, a lack of remanufacturing legislation was revealed to be the major hindrance to establishing operations in Brazil (Saavedra et al., 2013).

As international trade, trade barriers, including outright import bans, higher tariffs and fees, or overly stringent regulations, certification, and inspection requirements, increase the cost of remanufactured products (US-WTO, 2005). In many countries, e.g. Brazil, remanufactured products are classified as used goods, while Malaysia prohibits the import of the used automotive parts required for remanufacturing, effectively blocking remanufacturing (USITC, 2012). The third factor concerns Intellectual Property (IP) protection. Protection of IP represents an incentive for OEMs to undertake remanufacturing in order to protect their IP from IRs (Pagell et al., 2007).

In terms of environmental regulations, environmental concerns have prompted governments to enact regulations that constitute key drivers to the development of remanufacturing (Matsumoto, 2010). Östlin (2008) illustrate this with the example of legislation concerning remanufactured toner cartridges regulated under the WEEE[3] directive that strengthens remanufacturing through requiring the manufacturer to be responsible for post-consumption recycling.

[3] WEEE DIRECTIVE (2002/96/EC): Waste Electrical & Electronic Equipment requires producers to manage post-consumer recycling and disposal of electronic products effective August 13, 2005.

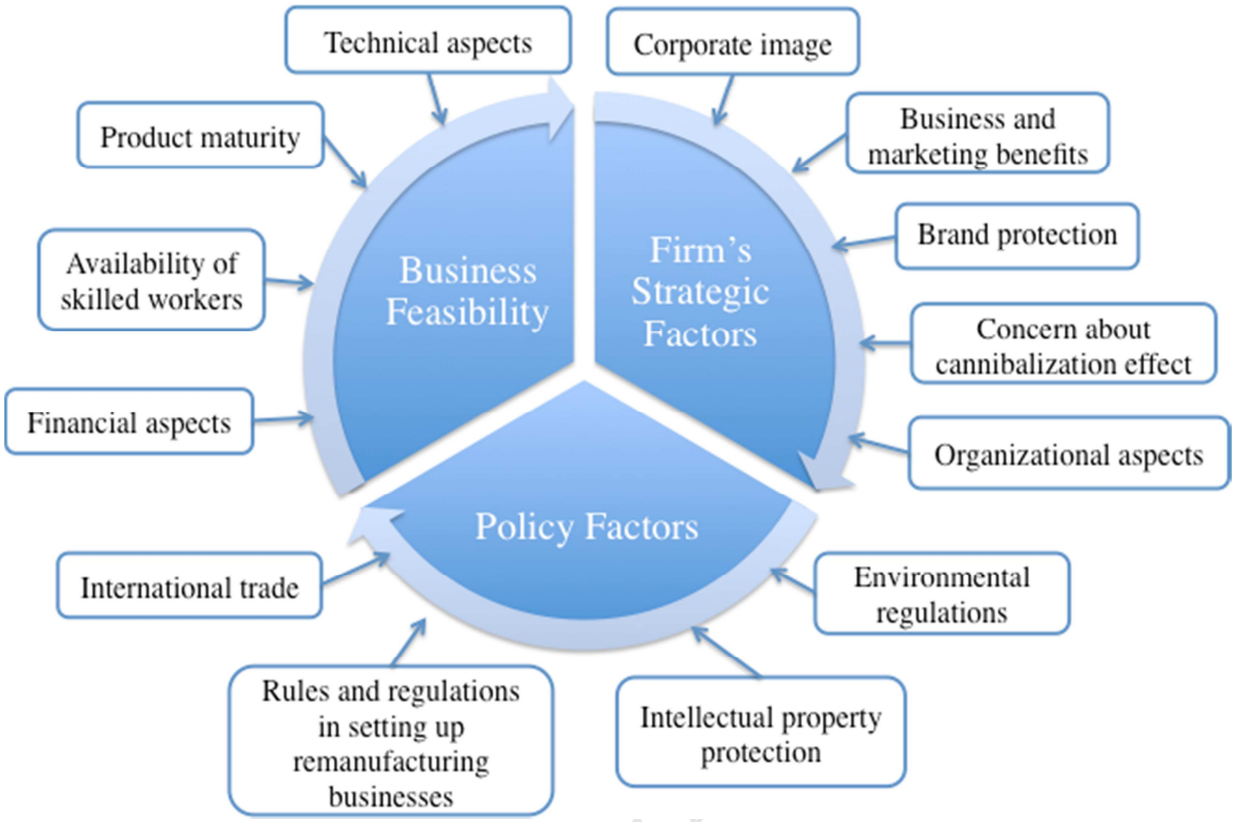

Fig. 1. A Summary of the Factors Influencing a Firm's Decision to Conduct Remanufacturing

3. Methods and materials

This study applied both qualitative and quantitative approaches employing industrial surveys administered to representatives of companies operating in three industries, namely automotive parts, photocopiers and agricultural machinery. A qualitative approach was conducted through semi-structured interviews using the open-ended questioning of key decision makers. A quantitative method involved analyzing responses to questionnaires. Here, standard deviation (S.D.), One-way ANOVA (Analysis of Variance), and t-test were applied.

A purposive sampling strategy was utilized as the tool for informant selection in order to gain greater insight, rather than probability sampling techniques. The significance of purposive sampling lies in identifying information-rich participants with the prerequisite depth of experience to permit in-depth analysis (Patton, 1990).

The key informants interviewed comprised business owners and executive managers, who have the authority to make decisions concerning undertaking remanufacturing. In view of the fact that there is currently no registration of remanufacturing firms in Thailand, we rely on an estimation of firms comprising approximately 270 operations[4]. The 41 sampled firms ~~thus~~

[4] It is crucial to note that remanufacturing firms in Thailand include both remanufacturing and semi-remanufacturing. The studies of Kohpaiboon et al. (2012) proposed the term "semi-remanufacturing" in the Thai case since the products under this category are to some extent similar to the products under rebuilding, reconditioning, and overhauling, but the quality derived from "semi-remanufacturing" seems to be higher. Semi-remanufacturing occurs based on the demand of Thai customers for cheaper product prices. Kohpaiboon et al. (2012) stated that heavily relying on the remanufacturing definition might lead to underestimating the potential and marginal utility of accrued environmental benefits for developing countries, including Thailand. What matters most is resources being re-used instead of being sent to be disassembled to become replacement parts, recycled, or dumped in landfill, which generates increased negative impacts on the environment.

constituted 15% of the overall total of remanufacturing firms (Table 1).

Table 1

Characteristics of Respondents Categorized by Industries

Item	Sub-item	Total firms	%	Auto-motive Part firms	%	Photo-copier firms	%	Agri-cultural Machinery firms	%
Industry	No. of firms	41	100%	16	39%	13	32%	12	29%
Actor	IR	37	90%	15	94%	12	92%	10	83%
	OEM	4	10%	1	6%	1	8%	2	17%
Firm Size	Small	26	63%	11	69%	9	69%	6	50%
	Medium	11	27%	4	25%	3	23%	4	33%
	Large	4	10%	1	6%	1	8%	2	17%
Ownership	Thai-owned	36	88%	14	88%	12	92%	10	83%
	Foreign-owned	5	12%	2	13%	1	8%	2	17%
New Product Sale	Sale	16	39%	4	25%	4	31%	8	67%
	Not sale	25	61%	12	75%	9	69%	4	33%
Cheaper than new OEMs	1-2 times	9	22%	-	-	5	38%	4	33%
	3-4 times	10	24%	7	44%	3	23%	-	-
	5-6 times	3	7%	3	19%	-	-	-	-
	N/A	19	46%	6	38%	5	38%	8	67%
Position of respondent	Owner	26	63%	11	69%	11	85%	4	33%
	Executive director	1	2%	-	-	-	-	1	8%
	Manager	12	29%	4	25%	2	15%	6	50%
	Senior Officer	2	5%	1	6%	-	-	1	8%

The number of selected remanufacturing firms was almost equal for the three industries: automotive parts (39%), photocopiers (32%), and agricultural machinery (29%). As represented in Table 1, almost all of the chosen firms were IRs (90%) and were mostly Thai-owned (88%). A total of 63% of all samples comprise small-scale firms[5], while 27% are medium-scale and only four are large. 39% of the sampled firms simultaneously operate businesses concerning new products, while the remaining firms focus only on remanufacturing operations (61%). Remanufactured products are one to six times cheaper than new OEMs.

The data collection process involving the 41 remanufacturing firms was undertaken over 16 months, from February 2014 to May 2015. The length of interviews varied from half an hour to two hours. The questions asked when conducting interviews were first tested on a firm owner with over ten years' experience within the automotive parts industry involving remanufacturing activities. His feedback was invaluable in evaluating and refining the comprehensiveness of our survey instrument.

Another industrial survey instrument, which was also applied to the same 41 interviewees, is the questionnaire. As it was important to ensure that the questionnaire was well structured, we sent it to six experts involved in remanufacturing operations, comprising four

[5] A small-scale enterprise has fewer than 50 employees, a medium-scale enterprise has fewer than 200 employees and in excess of these is seen as constituting large-scale (OSMEP, 2015).

business owners and two academics, and incorporated their feedback into our final instrument. The respondents were given a structured questionnaire and asked to indicate their responses on a 5-point Likert scale (Sekaran, 2000). The questionnaire was composed of three main parts: firm information, influencing factors when undertaking remanufacturing - derived from a literature review, and personnel information.

A version 22 SPSS statistics program was applied to enable a statistical analysis of the questionnaire responses. In order to calculate the scores of influential levels, descriptive statistical measurements, including means, S.D., and medians, were performed. The influential levels represent easy indicators, determining the levels of influencing factors. They were categorized into five influential levels: (1) not at all = 1.00-1.79, (2) slightly = 1.80-2.59, (3) somewhat = 2.60-3.39, (4) very = 3.40-4.19, and (5) extremely = 4.20-5.00.

Similarities and differences among factors represent another means of analysis in terms of offering a comparison viewpoint. Comparing group means was performed using both t-test and One-way ANOVA (Park, 2009). T-test was used to examine the mean differences between two groups: ownership (Thai or Foreign) and having remanufacturing with new product sales (yes or no). One-way ANOVA was applied to compare more than two groups: three industries and firm size (small, medium, or large). This was undertaken to test the significance of differences between variables at the 0.1 level of significance.

4. Results and Discussion

Figure 2 illustrates the mean scores of affecting factors through area dimensions: business feasibility, firm's strategic factors and policy factors, categorized by three industries, while Figure 3 shows an ordered list of thirteen influencing factors on average concerning the three industries.

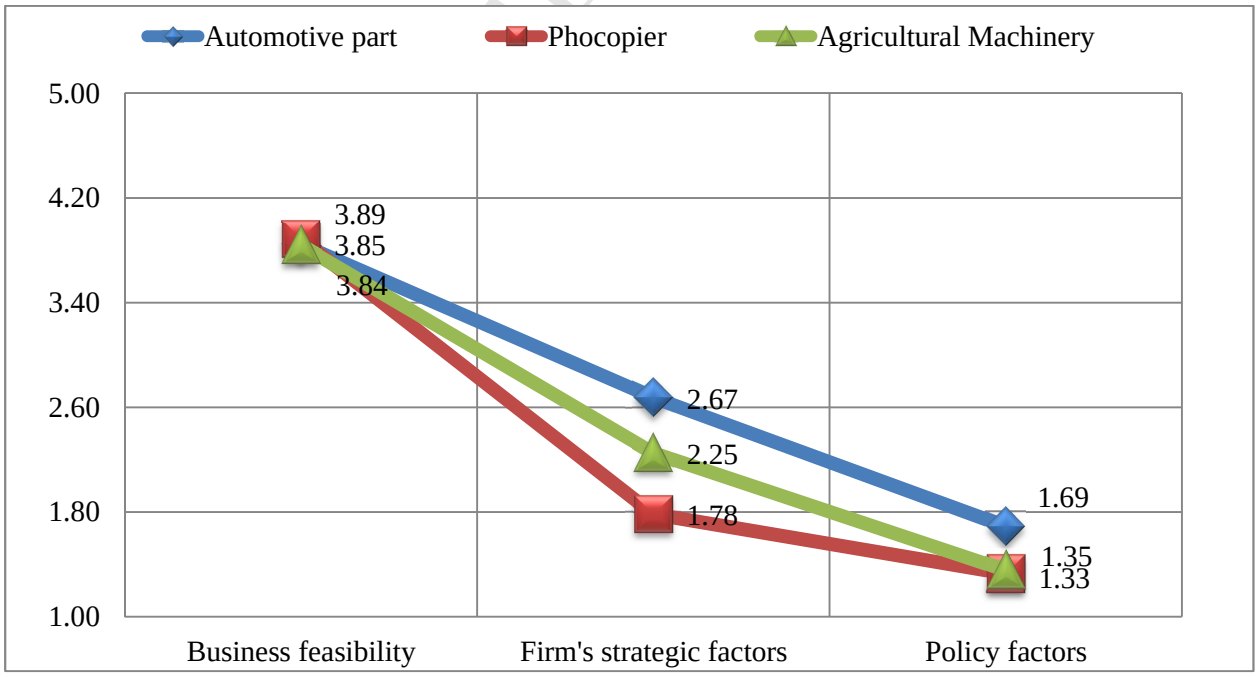

Fig. 2. Mean Scores of Three Areas Categorized by Industry

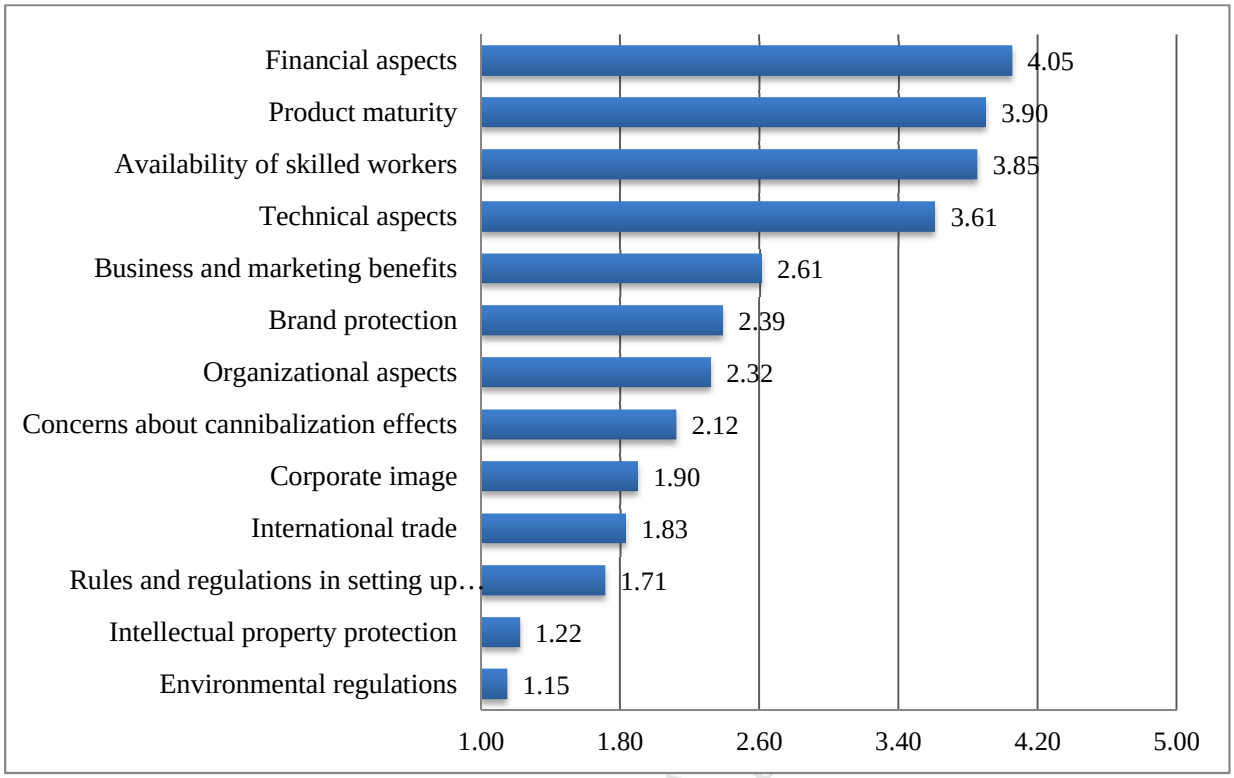

Fig. 3. Mean Scores of thirteen Influencing Factors

Regarding the three areas (Figure 2), business feasibility dominated a firm's decision to conduct remanufacturing, followed by firm's strategic factors being slightly influential, and policy factors not at all influential. Such evidence is found across all three industries. Within business feasibility (Figure 3), financial aspects are the most crucial variable, followed by product maturity, the availability of skilled workers, and technical aspects.~~, respectively.~~ The differences and similarities among the three industries may be elaborated as follows.

4.1 Business Feasibility

Business feasibility was ranked first as the most important driver for remanufacturing at a very influential level across all three industries.

4.1.1 Financial Aspects

Financial aspects represent the top ranked factor when firms make a decision whether to launch remanufactured products. The profit margins to be gained from remanufacturing are much higher than those derived from trading only in used products. This provides a strong incentive for industries to undertake remanufacturing. In this context, firms are concerned about both demand and supply costs.

In terms of demand, the cheaper prices offered for remanufactured goods which maintain reasonable quality standards represent the key attraction driving consumer demand. The prices of remanufactured photocopiers and agricultural machinery are between two and four times cheaper than new products, while automotive parts are up to six times cheaper. For both automotive parts and agricultural machinery, when the prices of remanufactured products are not sufficiently attractive, customers may turn to purchasing new products from China or used products imported from Japan instead. Note that both industries also conduct

remanufacturing by applying a tailored-made/customization approach, which is similar to the "remanufacturer-to-order" concept identified by Seitz (2007). This approach is becoming more popular in Thailand because it takes into account customer budget constraints. Recently, OEMs of photocopiers and agricultural machinery were able to resell their remanufactured products to CLMV countries as third hand goods.

Although the demand for remanufactured products in these industries has increased over the past decade, customer's negative perceptions about the quality of remanufactured products still remain and this is one of major hurdles for conducting remanufacturing in Thailand. This issue is also addressed in Abdulrahman et al. (2015) in the context of China and Matsumoto (2010) concerning Japan.

When considering the cost of remanufacturing, core acquisitions represent the key component within production costs. Across all three industries, there are two main avenues for core acquisition, domestic and imported, each involving a different approach. In domestic markets automotive parts are acquired through exchanging returned cores and remanufactured parts with the same specifications and with return incentives. Both OEMs within the photocopier and agricultural machinery industries acquire domestic cores from the system of a closed-loop supply chain. In the photocopier industry cores are commonly secured as a result of the expiration of five-year tenancy agreements. ~~However,~~ Agricultural machinery cores are obtained by exchanging returned cores from customers with new products and via repossession programs. Another source of core accessibility for all three industries is through import markets, especially goods from Japan, China and European countries. ~~However,~~ With both automotive parts and agricultural machinery, imported cores from Japan via auction lead to higher prices. This potentially raises the cost of remanufacturing. IRs tend to obtain cores via import sources, while OEMs mostly acquire them from domestic markets through the closed-loop supply chain mechanism.

Among the three industries financial aspects were regarded as more crucial in the case of photocopiers than with the automotive parts industry. ~~However,~~ From our ANOVA (Table 2) and Post hoc (Table 3) analysis, only photocopiers and automotive parts present any significant differences from firms' ratings. This could be due to the fact that firms in the photocopier industry have more channels available in order to maximize profitability than is the case for automotive parts. ~~Consequently,~~ They rated this factor significantly higher than automotive part firms. Remanufactured photocopier rental businesses enable their products to be remanufactured many times to maximize their utility. They generate more income from reselling their remanufactured products via export to CLMV countries as third-hand goods. Meanwhile, automotive parts firms encounter severe competition from new Chinese brands. These factors combined lead to diminished profits.

Table 2

One way ANOVA and T-test Analysis Results Categorized by Industry and Firm Size, Ownership and New Product Sales

Factor	ANOVA				T-test			
	Industry		Firm size[6]		Ownership		New product sales	
	F-value	P-value	F-value	P-value	T-value	P-value	T-value	P-value
Technical aspects	0.892	0.418	1.484	0.240	-0.395	0.695	-4.582	0.000*
Product maturity	2.085	0.138	0.323	0.726	-0.709	0.482	-0.178	0.859
Availability of skilled workers	0.290	0.750	0.479	0.623	0.531	0.599	-3.282	0.002*
Financial aspects	2.925	0.066**	0.060	0.948	0.885	0.382	-0.117	0.908
Corporate image	1.492	0.238	3.004	0.061**	-1.771	0.084**	-0.917	0.365
Business and marketing benefits	1.833	0.174	3.283	0.048*	-1.777	0.083**	-0.825	0.415
Brand protection	2.258	0.118	4.070	0.025*	-2.023	0.050*	-2.209	0.033*
Concerns about cannibalization effects	2.414	0.100**	1.266	0.185	-1.066	0.293	-0.637	0.528
Organizational aspects	1.636	0.208	0.365	0.294	-0.489	0.628	-1.404	0.168
Rules and regulations in setting up remanufacturing businesses	3.681	0.035*	0.931	0.403	-0.514	0.61	0.310	0.758
International trade	0.024	0.976	0.242	0.786	-0.319	0.751	-1.750	0.088
Intellectual property protection	0.381	0.685	18.612	0.000*	-1.794	0.147	-1.662	0.116
Environmental regulations	0.562	0.575	2.863	0.070**	-0.857	0.439	-1.695	0.111

Note: * P-value ≤ 0.05 and ** P-value ≤ 0.1
Source: Authors' calculations

Table 3

Post Hoc Analysis of Financial Aspects, Concerns about Cannibalization Effects and Rules and Regulations in Setting Up Remanufacturing Businesses Categorized by Industries

Factor	Industry	Industry	Mean Difference	Std. Error	Sig
Financial aspects	Automotive parts	Photocopiers	-0.572*	0.239	0.022
		Agricultural machinery	-0.188	0.244	0.447
	Photocopiers	Automotive parts	.0.572*	0.239	0.022
		Agricultural machinery	0.385	0.256	0.141
	Agricultural machinery	Automotive parts	0.188	0.244	0.447
		Photocopiers	-0.385	0.256	0.141
Concerns about cannibalization effects	Automotive parts	Photocopiers	0.981**	0.548	0.082
		Agricultural machinery	1.083**	0.561	0.061

[6] Post hoc analysis for all five significant factors were found that between large and medium as well as large and small firms were shown the statistically significant difference, whereas between medium and small size firms did not present the significant difference.

Factor	Industry	Industry	Mean Difference	Std. Error	Sig
	Photocopiers	Automotive parts	-0.981**	0.548	0.082
		Agricultural machinery	0.103	0.588	0.862
	Agricultural machinery	Automotive parts	-1.083**	0.561	0.061
		Photocopiers	-0.103	0.588	0.862
Rules and regulations in setting up remanufacturing businesses	Automotive parts	Photocopiers	1.144*	0.472	0.02
		Agricultural machinery	1.042*	0.483	0.037
	Photocopiers	Automotive parts	-1.144*	0.472	0.02
		Agricultural machinery	-0.103	0.506	0.84
	Agricultural machinery	Automotive parts	-1.042*	0.483	0.037
		Photocopiers	0.103	0.506	0.840

Note: * The mean difference is significant at the 0.05 level;
** The mean difference is significant at the 0.1 level.
Source: Authors' calculations

4.1.2 Product Maturity

All industries perceive product maturity as the second crucial factor for firms conducting remanufacturing in terms of product lifespan, technological change and complexity. It is worth remanufacturing products if their remaining lifespan is at least 80-100% the length of that of new goods and such products still offer high added value. A product is suitable for remanufacturing when technological change is slow and involves a low level of technological complexity. This is in line with findings in the prior literature arguing that the slow speed of technological innovation change increases the potential for firms to produce remanufactured products (Matsumoto, 2010).

4.1.3 Availability of Skilled Workers

The respondents from all industries confirmed that remanufacturing processes are labor intensive (Lundmark et al., 2009). This is in line with previous studies (Abdulrahman et al., 2015). OEMs concerned with agricultural machinery appreciate remanufacturing as an activity helping them to effectively manage and allocate members of their workforce alternately between producing new and remanufactured goods. An obstacle facing the recruitment of skilled workers in Thailand lies in deficiencies in their requisite quality and quantity. Specifically, as raised by respondents of several firms engaged in automotive parts production, the vocational education level workforce tend to lack the technical skills needed to operate remanufacturing processes.

Our t-test analysis (Table 2) suggests that firms across all three industries statistically rate this factor as significant in influencing the decisions of firms to conduct remanufacturing at the same degree. ~~However,~~ Firms in these three industries which sell both new and remanufactured products rate this to be more crucial than firms performing only remanufacturing. This could be because OEMs selling both new and remanufactured products do so under their own brand auspices. ~~Thus~~ The skilled workers are needed even more when producing new products under their own brand and especially to meet OEMs' standards.

4.1.4 Technical Aspects

Product design is a critical issue within remanufacturing, as pointed out by Ijomah (2009) because suitable product design is necessary to enable the ease of disassembly, cleaning, replacing and reassembling. Automotive part firms perceive this as slightly more important when making decisions to conduct remanufacturing than is the case with the other two industries, which require less sophisticated procedures. Specifically, OEMs of automotive parts regard product design as a tool to protect IRs from remanufacturing their cores. For all industries, proper design for remanufacturing has an impact on decreasing labor costs and increasing production efficiency.

Our t-test analysis suggests that firms selling new products along with remanufactured goods rated technical aspects as being of greater importance than firms conducting only remanufacturing (Table 2). This is because all the OEMs in this study produce new and remanufactured products, with half of them doing this under their own brand names. ~~Hence~~ They perceive technical aspects as being more important than IRs who produce unbranded products. As with technical aspects, for example, appropriate design for remanufacturing is a necessity for OEMs who produce new goods and then remanufacture their own products.

4.2 Firm's Strategic Factors

Firm-related strategic factors were ranked as the second driver influencing the establishment and operation of remanufacturing activities.

4.2.1 Business and Marketing Benefits

Green marketing initiatives potentially lead to both business and marketing benefits, especially for OEMs producing automotive parts and photocopiers. Such operations are able to augment their environmentally-friendly image by informing their customers how remanufactured products generate a comparatively diminished negative impact on the environment (Östlin et al., 2008). The OEMs of agricultural machinery operations specifically undertake remanufacturing as a strategy to create new activity. Meanwhile, the IRs of automotive part firms are involved due to the securing of spare parts and providing a service to their customers. This is relevant to studies in the literature arguing that remanufacturing is an important source of replacement (Östlin, 2008).

Our ANOVA findings (Table 2) reveal that large-sized firms perceive business and marketing benefits to be more critical for conducting their businesses than smaller-sized firms. Likewise, t-test analysis also suggests that this factor is significantly more crucial for foreign owners than Thai. All four large-sized firms in this study are foreign-owned OEMs which reveal the same results. Our interview responses affirm that OEMs consider green marketing strategies more seriously than those of IRs. They try to nurture their green image by informing customers how important it is that their remanufactured products generate a positive impact on the environment. ~~Thus~~ We find that this factor matters more for large-sized and foreign-owned firms in terms of deciding whether to conduct remanufacturing.

4.2.2 Brand Protection

In terms of brand protection, however, the results are quite different from previous studies because of the particular characteristics of firms who conduct remanufacturing in Thailand. The majority of firms in this study are IRs, which do not have their own brand

identities, while the literature mostly focuses on OEMs. IRs within these three industries run remanufacturing businesses to provide quality products to their customers, together with simultaneously building their firms' reputation and customers' trust. Their motivation is not connected to any specific brand identity.

Our ANOVA test (Table 2) suggests that large-sized firms regard brand protection as being more important than smaller-sized. Likewise, the t-test analysis also suggests that this factor is more crucial for foreign-owned than Thai-owned firms, together with firms selling new goods along with remanufactured products, rather than firms selling only remanufactured products. This is because all four large-sized firms in this study are OEMs, managed under foreign ownership, and selling both new and remanufactured products. They all have their own product branding. ~~Therefore,~~ Such OEMs are definitely concerned with brand protection and engage in remanufacturing to protect brand erosion by IRs.

4.2.3 Organizational Aspects

Organizational aspects were regarded as the third important consideration. Organizational flexibility and business alignment are necessary across all industries in order to implement remanufacturing. For example, representatives of OEMs in the agricultural machinery sector suggested separating remanufacturing sections from their original production operations in order to generate flexibility in their management processes. Photocopier firms refered to collaboration between sales and technical divisions in order to provide a better quality service to their customers. In the pertinent literature, this factor tends to be more significant with large-scale firms which have a hierarchical organizational management structure. ~~However,~~ Our ANOVA testing found a statistical insignificance in rating this factor between firms of different sizes in Thailand. This is potentially because the majority of sample firms are comparatively small with limited management complexity.

4.2.4 Concerns about Cannibalization Effects

In almost all of the firms across the three industries there was a consensus in that there is no conflict between remanufactured and new products in terms of any cannibalization effects because they target different market segments. Only one OEM in the agricultural machinery industry attempted to prevent the cannibalization effects through limiting remanufacturing production volumes. This variable was rated as less influential for firms in Thailand.

Among the three industries, our ANOVA (Table 2) and Post hoc (Table 3) analysis show that this factor is perceived as more critical for automotive parts than for photocopiers and agricultural machinery. ~~However,~~ There is no statistical difference between photocopiers and agricultural machinery. Automotive part firms rate this variable higher than their two counterparts because their markets for new and remanufactured automotive parts are closer substitutes. ~~Hence~~ They need to be more concerned about any conflict between new and remanufactured products.

4.2.5 Corporate Image

In view of the low awareness of environmental concerns as affecting corporate image, the respondents rated this as the least crucial factor. The firms still focus on their core businesses, rather than on corporate image. This is in line with the study of Seitz (2007) who

was unable to confirm ethical and moral responsibility as constituting a motive for engaging in the remanufactured automotive engine business.

Only two OEMs from the automotive parts and photocopier industries gave relatively more importance to environmental policy issues due to green corporate policy dictates emanating from their headquarters. OEM of a photocopier firm emphasized environmental concerns, instead of focusing solely on profitability.

Our ANOVA (Table 2) suggests that the large-sized firms regard corporate image as relatively more critical for conducting their businesses than smaller-sized. Likewise, t-test analysis also reveals that this factor is significantly more crucial for foreign owners than Thai. Note that all four large-sized companies in this study are both foreign-owned and OEMs and reflect the same results. All OEMs have their own product brand identities and take environmental considerations into account. They perceive this factor as more crucial when running their business compared to IRs who do not have a brand identity and are less concerned about the environment. OEMs must take corporate image into consideration because it represents a green policy encouraged by their headquarters. Conversely, IRs focus more on profitability, rather than being concerned about corporate image.

4.3 Policy Factors

Policy factors were identified as the least crucial area influencing the decision-making of firms across all three industries.

4.3.1 International Trade

In terms of international trade, although the influential levels of this variable across all three industries are statistically indifferent (Table 2), the direction of its influence on firms' decisions in these industries tends to be different. The Thai government has categorized cores as constituting used products and has not prohibited their import, unlike India and Malaysia (USITC, 2012). Due to the fact that there is no governmental prohibition on core imports, all industries perceived international trade as representing a significant business opportunity for conducting remanufacturing operations. Photocopier and agricultural machinery firms could also export easily through reselling their remanufactured products as third-hand goods in CLMV countries.

Several automotive part respondents complained that higher tariffs on imported used parts as cores for remanufacturing have become a de facto trade barrier. This causes increased production costs and decreased competitive advantage. This is similar to the case of Brazil where some regulations prevent core imports, which potentially has a negative impact on remanufacturing operations (Subramoniam et al., 2009).

4.3.2 Rules and Regulations in Setting Up Remanufacturing Businesses

The rules and regulations variable is considered as having a low level of influence in all three industries since, so far, there have been no relevant rules and regulations concerned with setting up remanufacturing businesses in Thailand. However, only one respondent of a photocopier OEM highlighted the effects of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal as a regulation supporting their remanufacturing business establishment.

Our ANOVA (Table 2) and Post hoc (Table 3) analysis show that this factor is considered to be more critical for the automotive parts than the other two industries. Although the majority of automotive parts firms are IRs, five of them seek to build their own product brand identities through focusing seriously on operating remanufacturing as a first priority. IRs of photocopier and agricultural machinery do not have their own brand-related concerns. ~~Therefore,~~ Firms in the automotive parts industry tend to need greater support in conducting their business through related rules and regulations established by the Thai government. From our interviews, automotive parts respondents mentioned asking the government to establish central operators to set up standards, quality control and testing systems related to remanufactured products.

4.3.3 IP Protection

IP protection was found to be quite unimportant in this study. The low scores revealed concerning this factor are in contrast to those identified in developed countries where IP is defined as constituting a crucial factor in determining remanufacturing activities (Pagell et al., 2007). This is likely to occur in developed countries because of the prevailing effective enforcement of regulations ensuring IP protection. ~~However,~~ Our ANOVA (Table2) testing reveals that large-sized firms defined IP protection as being more critical in conducting their remanufacturing businesses than smaller firms. All four large-sized firms in this study are OEMs. IP protection is more critical for OEMs than IRs, especially in terms of protecting product design and cores from IRs.

4.3.4 Environmental Regulations

Environmental regulations were determined as constituting the least influential factor affecting the decisions of firms to conduct remanufacturing activities. ~~Currently~~ There have been no direct environmental regulations regarding remanufacturing activities in Thailand. The relevant dictates are generally standard environmental or industrial factory regulations. They force all manufacturing businesses to be primarily concerned about waste disposal systems in working areas. This result is also found in other studies in emerging countries like China (Abdulrahman et al., 2015).

ANOVA testing (Table 2) reveals that large-sized firms perceive environmental regulations as being more important than smaller-sized. All four large-sized firms constitute OEMs operating under their own brand auspices. Environmental regulations represent more critical drivers for them because they emphasize conducting remanufacturing businesses as constituting a top priority when building their own brands. From our interviews, the respondent of a large-sized firm, an OEM in the photocopier industry, mentioned being focused on environmental policy through the Extended Producer Responsibility (EPR) initiative, operating remanufacturing in order to take responsibility for end of life products in line with policy directives determined by company headquarters. Meanwhile, IRs in small-sized firms engaged in agricultural machinery revealed that operating in Thailand represented a great opportunity for running remanufacturing without the involvement of environmental regulations limiting the lifespan of vehicles.

4.4 Discussion and Policy Inferences

Findings from our studies reveal not only the drivers for firms' decision to remanufacture in Thailand but also obstacles that firms in all three industries investigated

encounter. The absence of End of Life Vehicles (ELVs) directive and relevant laws and regulations, as well as the lack of proper promotion and support by the Thai government, especially in terms of research and development (R&D), standards and testing, are the key obstacles. The ambiguous information concerning remanufacturing leads to customers' negative perceptions regarding remanufactured products.

Within Thailand, three areas can be addressed to promote and strengthen remanufacturing. Firstly, the establishment of comprehensive policies and standards is needed, especially in the initial stage, to stimulate more firms to remanufacture. Directives such as the ELVs, policies such as the Extended Producer Responsibility (ERP) and any other relevant interventions related directly to remanufacturing should be established. Secondly, infrastructure, such as remanufacturing centers and standards bodies, with key responsibilities for setting up quality control, standards and specifications, testing systems and certification, are required. Thirdly, R&D and human resource development are needed to improve the soft infrastructure necessary for sustaining the development of remanufacturing.

5. Conclusions

Remanufacturing represents an option for the treatment of EoL products and is regarded as a great opportunity ensuring a win-win scenario for customers, businesses, the environment and society at large. This study aims to bridge the gap concerning remanufacturing knowledge by investigating the significant factors influencing firms' decisions to undertake remanufacturing using three Thai industries: automotive parts, photocopiers and agricultural machinery as case studies.

In all three industries, the area of business feasibility attains the highest score of being very influential, followed by firm's strategic factors being slightly influential, and policy factors the least influential consideration. Within business feasibility, the top three scores concern financial aspects, product maturity and the availability of skilled workers ~~respectively~~. Most firms emphasize profitability as being the key driver in deciding to initiate remanufacturing operations, rather than environmental considerations. All industries perceive product specifications as affecting the decision to conduct remanufacturing in terms of having a long product lifespan, slow technological change and the worthiness of remanufacturing investment. As the industries under consideration are labor-intensive, skilled workers are needed to expedite remanufacturing processes.

The firm's characteristics and the structure of the particular industry matter in ranking the factors influencing a firm's decision to conduct remanufacturing. Financial aspects, concerns about cannibalization effects and the prevailing rules and regulations involved in setting up remanufacturing tend to be more crucial for automotive parts firms than is the case in the photocopier and agricultural machinery industries. Large-sized firms tend to place a higher weight on corporate image, business and marketing benefits, brand protection, IP protection and environmental regulations than smaller-sized firms. Firms who sell both remanufactured and new products tend to allocate a higher score to technical aspects, the availability of skilled labor and brand protection than firms who produce only remanufactured products. Foreign-owned firms also perceive corporate image, business and marketing benefits, together with brand protection as more crucial than Thai-owned.

In terms of its contribution, this study potentially helps bridge the gap in the lack of remanufacturing knowledge. It may also assist policy makers in understanding the key factors

required for instigating successful remanufacturing operations. Our research also goes some way towards highlighting the deficiencies in infrastructure which need to be addressed in order to support remanufacturing. Further empirical studies should be extended to deepen such knowledge concerning different products, industries and countries. As this study focuses on a limited sample of three industries as case studies, future large-scale empirical surveys could extend the results enabling greater generalization and insight.

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Highlights

- Business feasibility is the most crucial determinant in driving the decision making of firms.
- Most firms emphasize profitability, rather than environmental considerations.
- The firm's characteristics and structure of industry matter in identifying influential factors.
- Strong governmental support is needed to develop remanufacturing in Thailand.